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An Approach for Identifying and Characterising Problems in the Iterative Development of C3I Capability

Gina Kingston, Derek Henderson and Rudi Vernik

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Information Technology Division
Electronics and Surveillance Research Laboratory

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ABSTRACT

This report presents a research approach that has been used to determine the key problems faced by the Australian Defence Organisation (ADO) in the iterative development of C3I capability. Repeated application of the approach, combined with knowledge of strategic and technological changes, could be used to assess process improvement activities.

The approach uses interviews of stakeholders in the Iterative Capability Development (ICD) process to gather information about the perceived problems. As well as documenting the approach used in a study of the key problems with the ICD process, this report illustrates the application of study design principles, such as methods for minimising potential biases in an interview-based study.

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DSTO Electronics and Surveillance Research Laboratory
PO Box 1500
Salisbury South Australia 5108 Australia

Telephone: (08) 8259 5555
Fax: (08) 8259 6567

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An Approach for Identifying and Characterising Problems in the Iterative Development of C3I Capability

Executive Summary

This report presents a research approach that has been used to determine the key problems faced by the Australian Defence Organisation (ADO) in the iterative development of C3I capability.

The approach used interviews of the key stakeholders in the Iterative Capability Development (ICD) process to gather information about the perceived problems. The interviews consisted of four main activities: an overview, evaluation of a model of the ICD process, problem identification and a problem elaboration phase. The interview process was constructed to reduce the possibility of biases. To this end, the elaboration of problems was supported by a questionnaire. Other measures adopted to improve the rigour of the study included:

- Early identification of the criteria used to assess the problems.
- Identification of key stakeholders in the ICD process and careful selection of study participants.
- Use of an interview process that included several avenues for verifying participants' contributions, such as requiring detailed information and examples of the problems.
- Use of tool support to document and confirm problems as they were discussed.
- Confirmation and clarification of the information recorded.
- Early evaluation of the approach during interviews with DSTO personnel.

The report also discusses insights into the approach obtained during its successful application. Sixteen participants in the ICD process were interviewed, including the entire C3I/IM Development Committee and three project managers. In particular, the report discusses the importance of evaluating not only the approach but also the implementation of the approach by the research team.

It is hoped that other researchers can benefit from this report and the detailed discussion of methods used to minimise the potential biases in an interview-based study.

Authors

Gina Kingston
Information Technology Division

Gina has been employed in the Software Systems Engineering Group of the Defence Science and Technology Organisation (DSTO) since graduating from the University of Tasmania with a BSc with First Class Honours in Mathematics in 1990. Her research interests include process improvement and empirical software engineering. She has conducted research into software costing, the analysis of software, and software acquisition. She is currently undertaking a PhD in Software Reviews through the School of Information Systems at the University of New South Wales and working on the JOint Reviews of Software (JORS) and Iterative Capability Development (ICD) tasks at DSTO.

Derek Henderson
Information Technology Division

Derek Henderson has been with the Australian Defence Science and Technology Organisation (DSTO) since 1991. Prior to that he was with the Ministry of Defence (MOD) UK where he was sponsored to take a degree in Electronic Systems Engineering at the Royal Military College of Science, Shrivenham, UK. Since joining DSTO he has undertaken a number of studies including a review of requirements specification practices in Navy and an investigation into the suitability of Evolutionary Acquisition for the procurement of complex systems. Derek is currently researching iterative techniques for developing command and control systems.

Rudi Vernik
Information Technology Division

Dr. Rudi Vernik is employed as a Principal Research Scientist and is Head of Software Systems Engineering Group. His research interests focus on the definition, development, and application of new systems and software engineering approaches to support Defence in its development of capabilities that will facilitate knowledge and information-based warfare. His group is currently undertaking research in the areas of systems visualisation, component-based software engineering, systems characterisation and modelling, systems dynamics, and evolutionary capability development processes. Rudi has a Ph.D. in Computer and Information Science (Software Engineering) from the University of South Australia. He also has a Bachelor of Electronics Engineering (with Distinction) and a Diploma of Communications Engineering from the Royal Melbourne Institute of Technology.

Contents

1. Introduction

This report describes an approach that has been used to identify and characterise problems in the Iterative Capability Development (ICD) of C3I.

The approach was designed around interviews with stakeholders in the Australian Defence Organisation (ADO). The approach was used to identify the stakeholders' perceptions of current problems in the ICD process and the impact of these problems on the delivery of C3I capability to the Australian Defence Force (ADF). The objectives of the study were to document these problems, to analyse the impact of the problems, and to identify areas of further research that have the potential to improve the ICD process. It is believed that the repeated application of the approach, combined with knowledge of strategic and technological changes, could be used to evaluate the impact of process improvement activities. (See Section 6).

The report includes a brief overview of the ICD process (Section 2), the research objectives and a summary of the approach (Section 3), and a discussion of the research method (Section 4). For simplicity, these sections discuss the design of the approach in terms of the single study already completed. The results of this study are reported separately in (Henderson and Kingston 1999). It is believed that the credibility of these results is enhanced through the rigorous approach that was used and which is described in this report.

This document may also be useful to researchers conducting similar studies in other areas, as this document discusses the rationale behind the approach. Section 4 discusses how potential biases were addressed in the design of the approach, Section 5 discusses lessons learned while conducting the interviews, and Section 6 discusses the implications for other researchers. However, researchers are advised to also consult other texts; this report is not intended as a tutorial on empirical techniques and it does not provide a detailed discussion of alternative approaches. Ellis (1994) provides a well-structured, easy to read, introduction to empirical techniques in general. Yin's book (1994) on case studies is worth reading, and Denzin (1994) provides a more detailed collection of papers on specific techniques, such as observational techniques (Adler and Adler 1994) and interviews (Fontana and Frey 1994).

The results of studies involving interviews often lack credibility because of the subjective nature of the participants' contributions, the *ad hoc* manner in which participants are selected, and because the views of the researchers can influence the participants. In order to address these criticisms, the approach was designed with the following features:

- Identification of key stakeholders in the ICD process and careful selection of study participants.
- Early identification of the criteria used to assess the problems.
- Use of an interview process that included several avenues for verifying participants' contributions, such as requiring detailed information and examples of the problems.
- Use of tool support to document and confirm problems as they were discussed, and to later analyse problems.
- Confirmation and clarification of the information recorded.
- Early evaluation of the approach during interviews with DSTO personnel.

The design of the approach had to balance the desire to use a rigorous, scientific, approach; the desire for flexibility in the interview process; and awareness of interviewees' time constraints. Thus, the research approach has some limitations when considered from any one of these viewpoints. For example, the selection of participants was not rigorously defined before the interviews; it was modified after the initial interviews. The participants tended to focus on recent problems and did not always constrain their responses to discussions of first hand experiences. Nevertheless, we believe that, because this approach was used, the results of the study are more credible than could have been achieved with an *ad hoc* series of interviews.

2. Iterative Capability Development (ICD)

This section describes the ICD domain for which the approach was developed. The term ICD was devised by the researchers to encapsulate all the processes used by Defence to plan, develop, acquire, maintain and evolve C3I capability in an iterative manner. It includes, but is not limited to the high level conceptual planning that occurs in C3I Capability Development Division, the acquisition processes used by the Defence Acquisition Organisation (DAO), and the processes used by the support organisations to maintain C3I capability.

Defence has gradually adopted ICD over the past few years. Previously, development was accomplished using the traditional or 'Big-Bang' approach. In the traditional approach, the phases are conducted in a linear manner; requirements are set at the start of an acquisition; and there are few feedback loops. For the development of C3I capability, iterative approaches that incorporate feedback loops are generally preferable to the traditional approach for two main reasons. First, C3I systems need to be adaptable to cope with rapid changes in the strategic environment, and subsequent changes to operational requirements. Second, the effectiveness of C3I systems is dependent on the use of modern information technology (IT), which is also subject to rapid change. The traditional approach does not have the flexibility to cope with this high rate-of-change.

Figure 1 shows the various organisations that contribute to the ICD process and the main interactions between the organisations. This diagram documents the researchers' understanding of the ICD process before any interviews were conducted. It was used as a discussion point at the start of the interviews and provided a framework for recording the interviewees' knowledge of the ICD process. The main limitation of the model is that it only represents the DAO perspective and does not include a general Defence Information Systems Group (DISG) perspective. Furthermore, the Joint Support Agency (JSSA) was not part of the DISG when the model was developed.

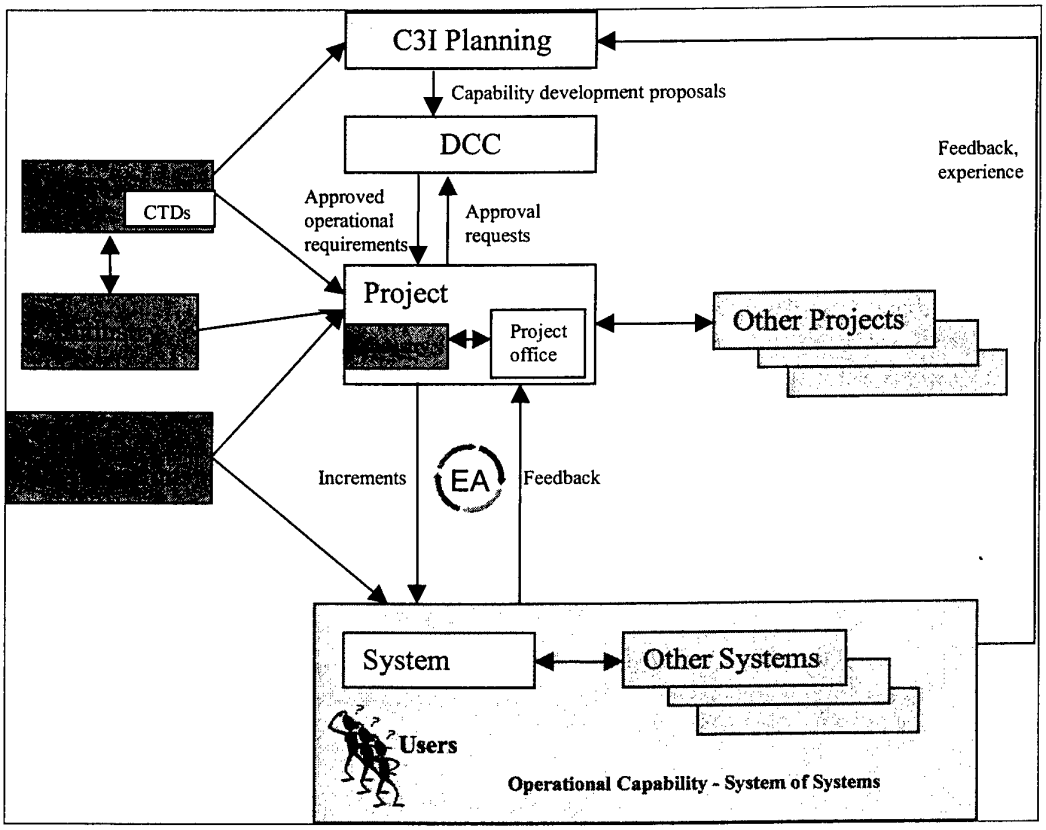

Figure 1. Iterative Capability Development.

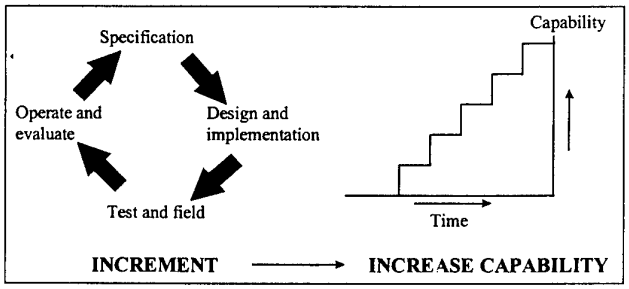

Figure 2. EA – an iterative approach

Evolutionary acquisition (EA) is central to ICD. In recent years, the DAO formally introduced EA and it is now used on a several projects including the major command support systems (CSS) and a number of Communications projects. The main thrust of EA, as illustrated in Figure 2, is the incremental specification, design, implementation, test, delivery, operation and maintenance of systems. Delivery of each incremental release increases the overall capability of the system. In this way, users of the system get early access to functionality and are encouraged to provide feedback on functionality and performance. The feedback is used in subsequent increments to shape the development of the system as it evolves to its final form. See (Henderson and Gabb 1997) for a detailed discussion of EA.

EA is only one aspect of the ICD process, albeit an important one. EA involves a fundamental shift in the way that Defence acquires equipment; one that requires changes not only to the DAO, but also to the other processes used in the development of C3I capability. Many of the processes required for successful EA are different to those used on traditional projects (Defence Capability Committee 1998). For example, the project approval process used in a traditional project is not suitable for an EA project. Departments within the ADO that contribute to the ICD process include, but are not limited to:

- C3I Capability Development Division, who develop capability development proposals for consideration by the Defence Capability Committee (DCC).
- The Defence Capability Committee, which approves an acquisition.
- The DAO project offices, which are responsible for acquiring a system within the guidelines established by the DCC.
- The users, who request, use and evaluate the acquired capability.
- DSTO, who provides input to the process through advice, research, and the development of Capability Technology Demonstrators.

While the approach has focused on ICD in the ADO, industry also has a key role in the ICD process.

It is inevitable that there will be problems in an activity involving so many departments and so many new processes. The aim of the approach was to enable those problems to be identified, and their impact to be qualified and quantified.

3. Approach

This section summarises the approach designed to investigate problems in the ICD of C3I. Section 3.1 discusses the objectives of the approach, Section 3.2 outlines the activities conducted, and Section 3.3 discusses the criteria used to evaluate problems in the ICD of C3I. Section 4 discusses the design of the approach in more detail, focusing on how the design reduces the likelihood of biases affecting the results of studies that use the approach.

3.1 Objectives

The research approach was designed to meet two main objectives. The first objective, O_1 was to identify problems that would benefit from further research. As shown in Figure 5, a two-step approach was used to identify research problems. The first step was the identification of the problems encountered by Defence personnel involved in the ICD process. The second step was the characterisation of these problems. This not only allowed the identification of research problems, but also provided a baseline against which the results of process improvement activities can be assessed. The second objective, O_2, was to evaluate and refine the model of the ICD process given in Figure 1.

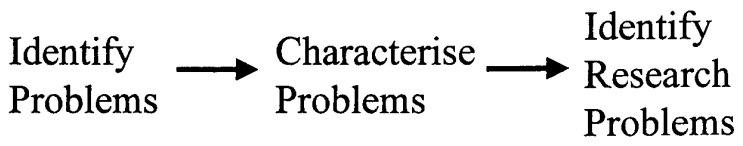

Figure 3: Steps in identifying problems that would benefit from research.

3.2 Outline of the Approach

This section outlines the research approach, as it was implemented in the completed study. The research approach was based around interviews with key stakeholders in the ICD process. As shown in Figure 4, the interviews form only part of the approach; additional activities were conducted before and after the interviews.

Before the interviews, the participants were supplied with information to allow them to prepare for the interviews. It provided background material and suggested activities that they might conduct to prepare for the review. For example, they could compile a log of problems encountered during the week prior to the interview.

The interview itself consisted of the following four steps:

1. **Overview**. The researchers introduced themselves and explained the interview process.
2. **Evaluate Process Model**. The ICD process model (Figure 1) was discussed and the interviewee's role in the process was identified and discussed. This step had two purposes: it addressed objective O_2, as it allows deficiencies in the model to be noted and used to refine the model; and it was a natural introduction to the next activities, which related to objective O_1.
3. **Problem Identification**. Once the participants had started talking about their role in the ICD process, and the interactions they have with the other entities in Figure 1, the participants were encouraged to discuss the problems that they had encountered in that role. Most participants required little or no encouragement to discuss the problems they had encountered.
4. **Problem Evaluation**. After problems had been identified, they were assessed against the research criteria discussed in Section 3.3.

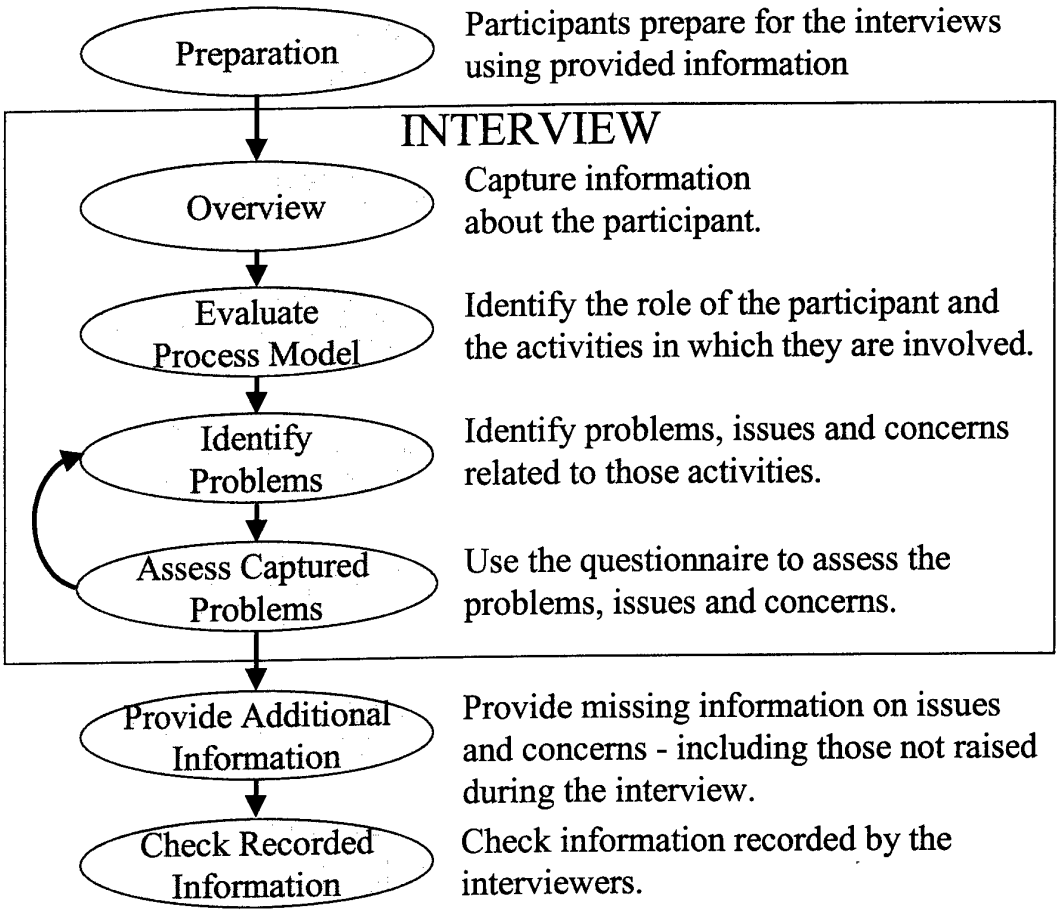

Figure 4: Activities involving the interview participants.

After the interview, the participants were given the opportunity to provide additional information and to check that the information recorded during the interview accurately reflected their opinions and experiences.

3.3 Identifying and Characterising Potential Research Areas

The information used to assess the problems was based on seven criteria that should drive the selection of ICD research problems, and the research approach used to address these problems. These criteria are summarised in Table 1.

Table 1: Research Criteria

Criterion	Description
Problem Areas	
C1.	Perceived as a problem by the stakeholders.
C2.	Impact on the iterative capability development process.
C3.	Potential impact of solutions.
Research Approach	
C4.	Able to be empirically evaluated, using a scientific approach.
C5.	Able to be evaluated within a reasonably short time frame (3-6 months).
C6.	Able to control or manipulate problem and solutions for evaluation.
C7.	Able to be effectively and efficiently evaluated by the researchers.

The first three criteria are concerned with the potential improvement to the ICD process. As shown in Figure 5, there should be a problem, it should impact the ICD process, and it should be possible to address the problem. (Note that the approach described in this report focuses on perceived problems, rather than on uncovering hidden problems.) The next three criteria consider the approaches that can be used to research the problem. In particular, they are concerned with the susceptibility of the problem to empirical investigation. The final criterion is concerned with the suitability of the problem for research by a particular research team.

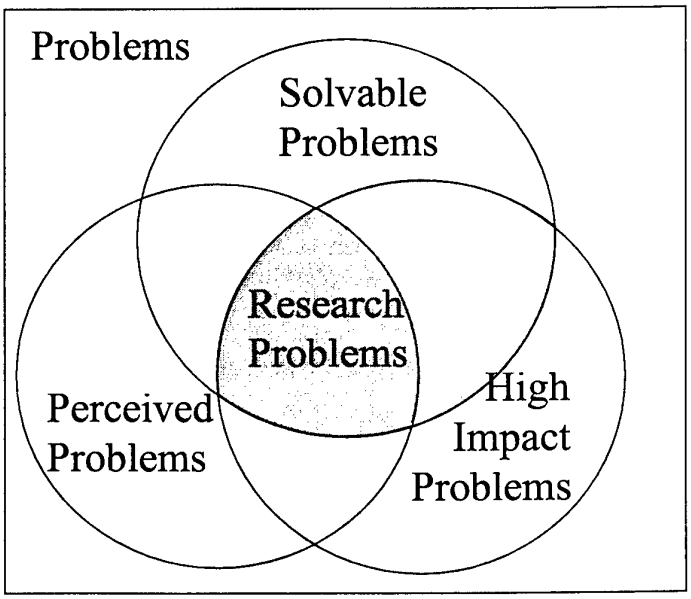

Figure 5: Identification of research problems.

The seven criteria are now described in more detail.

C1. The key stakeholders in the ICD process should perceive the problems as relevant. This criterion is required to ensure that the future ICD research is of interest to, and is relevant to, Defence. It would be difficult to justify, and receive support for, work that was not deemed important by the key stakeholders. For each potential problem identified and recommended

for further study, the researchers should aim to determine whether the problem is real or perceived.

C2. The problems should have a significant potential impact on ICD process. Problems might affect a project's cost, its schedule, the quality of the delivered system, and the relationship between the contractor and the ADO. Alternatively, problems might be irritating and annoying, but have little impact of the outcomes of the ICD process.

C3. It should be possible to identify potential solutions, or partial solutions, to the problem that would have a high impact on the perceived efficiency or effectiveness of ICD. The key stakeholders might be able to identify potential solutions. Alternatively, the nature of the problem might suggest avenues for determining a solution.

C4. The research approach used to investigate the problems will depend on whether or not the problems and their potential solutions are amenable to rigorous empirical evaluation. To be amenable to empirical investigation, the scope of the problems and potential solutions should be clearly identified and the outcomes of changes to the process should be measurable. These measures might be absolute – such as the number of problems reported during the first year of operation – or based on subjective evaluations – such as the result of a survey of users. Some problems will require additional theoretical and practical investigation as well as, or instead of, empirical investigation.

C5. The timescale for conducting the research should be considered. The ICD process is undergoing rapid change, so for many research programs (empirical or otherwise) the timing of the research is a critical factor. Furthermore, the potential benefit of any research program to existing projects may need to be considered.

C6. If an empirical investigation is being considered, it should be possible to manipulate the ICD process to assess the impact of potential solutions. That is, ideally, it is possible to compare the usual problem with the proposed solution, to determine whether or not the proposed solution does improve the ICD process.

C7. The researchers should have the relevant experience and expertise to address the problem.

The objective of the approach described in this report is to enable information that can be used to assess the first six criteria to be captured. The results of the study, as reported in (Henderson and Kingston 1999), indicate the relative scores of the problems against the first criteria, discusses the other criteria, and identifies areas where further study is desirable. Section 4.3 describes how the criteria were assessed. It should be noted that problems did not need to score highly in all seven areas to be selected. Indeed, it would be surprising if any problems did score highly in all seven areas. Section 4 now considers the design of the approach in more detail.

4. Research Method

Section 3.2 discussed how the approach consisted of interviews with key stakeholders in the ICD process. This approach was chosen to meet the first objective of identifying areas where further research is desirable. As discussed in Section 3.3, the views of the key stakeholders were one of the criteria used to assess whether or not problems should be researched. Other

approaches, such as the use of case studies, experiments, or fixed questionnaires were not believed to be suitable as it was anticipated that stakeholders from different parts of the ICD process would encounter different problems. A case study detailed enough to identify the problems and broad enough to cover all the areas was not feasible. An experiment or a rigid questionnaire could not be used because the problems were not known in advance.

However, an interview-based research design has several potential problems. The results of such studies can be biased because the views of stakeholders who are interviewed do not reflect the views of all the stakeholders; because of limitations in the participants ability to provide unbiased information; because the participants do not have all the information; or because the researchers influence either the information provided by the participants, or its interpretation.

The approach used to investigate problems in the ICD process was designed to limit the impact of these potential sources of bias. Section 4.1 discusses the selection of participants, and how the problem of selecting a representative sample was addressed. Section 4.2 discusses how the potential biases of the researchers were addressed in the design of the questionnaire. However, Section 4.3 discusses how the detailed construction of the questionnaire was influenced more by the potential biases of the participants, which also affected the manner in which the interviews were conducted (Section 4.4). Finally, Section 4.5 describes the evaluation of the interview process.

4.1 Participants

The results of a study will be biased if the interviewees do not form a representative sample from the population of interest. As described in Section 2, the ICD process involves participants from at least six groups – Planning, Acquisition, Industry, Users, Support Organisations and DSTO – each of which consists of a large body of people. Therefore, the population of interest is reasonably large. Furthermore, the researchers did not, and still do not, have an accurate record of all the personnel involved in the ICD process, even with the restriction to those ADO personnel involved in the acquisition of C3I capability.

Therefore, the approach used in the study was to combine representative samples from clearly identified groups with a series of interviews selected using a more *ad hoc* approach. At the start of the study, one clearly defined group of ICD personnel were identified, the managers of C3I projects. These managers covered approximately 20 projects, or sub-projects, that vary according to their branch or capability area (Communications or Command Support Systems (CSS)) and the stage of the projects (pre-contract, post-contract or support). Consequently, it was decided to interview three project managers of major projects, who covered all of these areas. The managers of a pre-contract Communications project, a post-contract CSS project and a support project were selected.

It was decided to supplement the interviews with these participants, with interviews of DSTO personnel and personnel recommended by the project managers. The study was to clearly indicate that the results related to these participants were *ad hoc* and that they should be treated with caution. However, during the course of the interviews, another well-defined group of participants was identified. This group is the C3I/IM Development Committee, more commonly referred to as the Gang of 7 or the G7. Therefore, the list of interviewees was extended to interview all of the G7 and to clearly identify their contribution to the results of the study.

Thus, three groups of participants were identified with different properties and the corresponding results should be treated differently. The results from the G7 can be treated with more confidence than the results in the other sections. These results should reflect the opinions of the G7 because the entire sub-population was sampled. The results from the project managers can also be treated with confidence. However, the list should not be assumed to be complete, or the ranking applicable to all projects, because the entire population was not sampled. The final group of results should be treated with caution, because the participants were selected in an *ad hoc* manner. They were included to give breadth to the study, and not to strengthen its validity.

4.2 Researchers and the design of the questionnaire

Researchers have the potential to bias the results of the interview-based studies in two ways. First, the researchers might influence the study participants' identification of problems or the discussion of these problems. Second, even if the information discussed during the interview is not biased, the researchers can bias the results of the study by the way that they interpret and encode the information.

The study used several measures to reduce the likelihood of biases being introduced by the researchers. The main measure, which is discussed in this section, was to use a semi-structured interview process. This involved identification of the problem areas by the study participants and the use of a standard questionnaire to ensure that consistent information was collected about each problem. A second measure was the use of two researchers, as recommended by Adler (1994). The researchers discussed the interview and reconciled their interpretations of the discussions immediately after the interviews. The researchers can also tried to ensure that leading questions were not used. Other methods for reducing biases are discussed in Section 4.4.

Interviews can be structured, unstructured and semi-structured. A structured interview consists of a series of well-defined questions that are asked in a particular order. In a structured interview, all responses and discussions must fit within a pre-defined framework; there is no opportunity to explore anticipated avenues. When conducting a structured interview, it can sometimes appear that the researchers are not listening to, or are not responsive to, the study participants. Opportunities to capture important information can be lost. In contrast, an unstructured interview has no predefined structure, and the direction of discussions depends almost entirely on previous discussions. This can result in the collection of interesting information. However, it is difficult to collect consistent information from all the interviewees using this approach. Consequently, a semi-structured process, which has elements of both the structured and unstructured approaches, was used.

In a structured or a semi-structured interview process, the researchers can use questions with either open-ended or closed-ended response options, while only questions with open-ended response options are normally used in an unstructured interview process. Closed-ended questions are those for which a limited set of responses are possible; while the response options for open-ended questions are not limited. For example, a question concerning the name of a person or project normally uses open-ended response options, and a question concerning the duration of a project may use either closed-ended response options, where the interviewee has to select a duration from a list of options, or open-ended response options.

Empirical scientists generally prefer closed-ended response options, because these response options require less coding and are less subject to biases in interpretation (Ellis 1994). However,

closed-ended questions cannot be used to identify areas that have not previously been considered by the researchers. This limitation means the study of problems in the ICD process should not rely on questions with close-ended response options. That is, the approach used should enable the identification of all problems encountered by the ADO in the development of C3I capability; the problems should not be limited to those foreseen by the researchers.

However, if the approach relied solely on questions with open-ended response options, then the likelihood of the researchers introducing unintentional biases during the coding of the discussion would be high. Therefore, the selected approach was to use both open and closed-ended response options. First, discussions with the participants were used to identify problems that they had encountered. To ensure that all the participants considered the same problem domain, the discussions focused on the participant's role in the ICD process (Figure 1). Second, for each problem, the participants were asked to answer a series of more specific questions concerning the problem. Many of these questions used closed-ended response options. In particular, the information used to rank the problems was obtained using questions with closed-ended response options.

The next section discusses the specific questions used to evaluate the problems. It discusses how the researchers coded the information when the participants were not able to select a response from the pre-defined list.

4.3 Variables and Analysis Approach

The questions used in an interview need to be carefully designed to avoid inaccuracies and biases that arise from the participants in the study. Ellis (1994) identifies four possible sources of inaccurate information: 1) failure to understand a question, 2) failure to recall information, 3) indecision and 4) dishonesty. The approach that is recommended in this report addresses the first problem by using semi-structured interviews rather than a structured interview or a survey approach. Discussion of the second and third problems is deferred until Section 4.4. This section discusses how the final problem was addressed during the design of the questionnaire.

The problem of dishonest information occurs when the participants either deliberately or unintentionally provide false or misleading information. For example, the participants in surveys and interviews are often reluctant to provide information that they believe could adversely affect their image or reputation. Sometimes participants say what they believe the interviewer wants to hear. Very occasionally, participants will provide information intended to sabotage the results of a study. While these problems cannot be avoided, they can be limited by requiring the participants to provide detailed information about any area that they discuss. The approach used in the study of problems in the ICD process was to ask the participants to identify problems that they had personally encountered. The participants were asked to provide additional information, to minimise the likelihood that any area identified was derived from second-hand information, or was outside the participant's area of expertise. They were asked to describe the problem, to provide examples of the problem, and to qualify and quantify the problem.

Table 2: Assessment Technique.

Criterion	Assessment
C1.	Quantitative
C2.	Quantitative
C3.	Qualitative
C4.	Qualitative
C5.	Quantitative
C6.	Qualitative
C7.	Not assessed

Consequently, the data collected during the interviews consisted of qualitative data collected during discussions with the survey participants, and quantitative data collected using the questionnaire. Table 2 shows the assessment techniques used for each of the criteria discussed in Section 3.3.

During the discussions the participants were encouraged to describe their role in the ICD process and any difficulties or problems that they had encountered. From this discussion, a list of problem areas was identified by the researchers, and confirmed with the interviewees. Qualitative information about each problem area was obtained from additional discussions focused around open-ended questions documented in a questionnaire. These questions were used to collect consistent information about each problem, including descriptions of the problem area, examples of the problem, the impact of the problem and potential solutions to the problem. This information was used to assess the qualitative items given in Table 3.

Table 3: Qualitative Assessment

Criterion	Assessment Technique
C3.	The key stakeholders were asked to identify potential solutions to the problem. The researchers should also consider potential solutions after the interviews.
C4.	The researchers used the description of the problem and the potential solutions to determine whether or not it is susceptible to rigorous empirical evaluation. A problem was deemed susceptible to rigorous empirical evaluation if qualitative and quantitative measures to assess the impact of the problem could be determined.
C6.	The researchers used the description of the problem and the potential solutions to determine whether or not the relevant activities could be manipulated to evaluate the problem. This depends on the amount of changes required to existing processes and the perceived difficulty in convincing study participants to accept the changes.

In addition to these general discussions of each problem area, the participants were asked to provide quantitative information on the problems. The collection of this information was supported by a series of questions with closed-ended response options, as in Table 4. The criterion C1 required the participants to indicate the importance of the problem on a scale of 1 to 10. For consistency, they were not provided with the opportunity to use alternative measures of importance.

Table 4: Quantitative Assessment – Standard questions

Criterion	Survey Questions
C1.	**How important is the problem?** Please answer according to your general impressions. Later questions will focus on specific criteria. 1 2 3 4 5 6 7 8 9 10 Low Importance High Importance
C2.	**Consider the impact of the problem on C2 capability increments or (sub-) projects in the following areas.** Give examples of the impact and then try to quantify the impact (eg percentage change). **Cost** **Schedule** **Quality** **Interoperability** **Client/Developer relations**
C5.	**What is the time delay between the start of the activity involving the problem and its impact?** < 1 day (Immediate) < 1 week < 1 month < 3 months < 1 year > 1 year Other _____(Please specify) (eg event driven – upon release etc) **How frequently does the activity involving the problem occur?** Continual Every week Every month Every year Every release Every project Other _____ (Please specify)

Five questions were used to address the criterion C2 that concerns the impact of problem. Three of these, cost, schedule and quality, are commonly used in the evaluation of projects. Interoperability is an aspect of quality that is considered separately because it has become increasingly important. The final area is one that is not normally considered, but which can affect not only the outcome of a single project, but the outcome of future projects. It is the interaction between Defence and Industry. Alternative measures, such as user satisfaction were not chosen because they are too indirect and difficult to quantify. However, not all interviewees were able to provide quantitative information to address the five areas used to address criterion C2. Therefore, the participants were also asked to provide additional qualitative information describing how these five areas were affected.

Two questions were used to address criterion C5, which concerns the time frames associated with the problem. The two questions concerned the time lag between the inception and the realisation of the problem, and the frequency with which the problem occurs. Standard, closed-ended, response options were used for these questions; although, the participants were given the option of providing a response that did not fit the pre-defined responses.

The quantitative data was analysed using standard statistical techniques. However, the analysis was limited to calculating the frequency with which the problems were raised and the median of the response options, because of the small number of interviews conducted. (Note that it was possible to use the median (middle) response rather than the mode response (the most common response), because the response options for all of the questions in Table 4 were ordered.)

4.4 Conduct

This section builds on the summary of the approach provided in Section 3.2. The approach was designed to reduce the likelihood of biases due to the study participants' failure to recall information or indecision, and to reduce the impact of any biases introduced by the researchers while recording and coding information.

Figure 4 shows the activities that were undertaken by the study participants before, during and after the interview. Several of these activities were included to limit the biases that could arise if the participants failed to recall information.

The participants were given the opportunity to prepare for the review (Preparation). They were provided with a short statement documenting the purpose of the interview (Appendix A), a blank questionnaire (Appendix B), two worked examples of problems (Appendix C), and a copy of the ICD process model (Figure 1). It was suggested that they prepare for the review by considering problems that they had encountered in the ICD process. The participants were generally given about a week to consider, and note, the problems they encounter in the ICD process. This meant that the participants did not need to rely solely on their ability to recall information during the interview. However, it should be noted that the researchers had no control over the participants' preparation.

The interview process was also designed to reduce potential biases that could arise if the participants failed to recall information. The researchers recorded information during all the activities that were conducted during the interview. The information collected during the Process Model Evaluation stage was used to crosscheck the information collected during the Problem Identification stage. For example, consider a participant who is involved in a particular ICD process, but who does not state any problems related to that process. This could occur because of failure to recall problems related to the process, or because they have not encountered any problems with that process. When the information between the two interview stages is crosschecked, it provides an opportunity to clarify the participant's comments and a second opportunity for problems related to the ICD process to be identified.

The identification of problems was conducted separately to the assessment activity to ensure that the participants were not interrupted during the identification of problems. If the participants were interrupted while trying to identify problems, it is possible that they would have failed to recall some problems. At natural breaks in the discussions, or approximately half way through the interview, the participants were asked to assess or characterise the problems that they had identified. This information was recorded in an application developed using MS Access. This activity was driven by the questionnaire previously discussed. The characterisation of one problem area often led to another problem identification round.

The final steps in the process (Provide Additional Information and Check Recorded Information) were used not only to reduce biases that could be caused by the participant's failure to recall information during the interview, but also to reduce the impact of biases introduced by the researchers during the coding of the information. The participants were given copies of the information recorded during the interview. To address potential recall biases, the participants were asked to complete missing information, and to provide information about any problems that were not discussed during the interview process. To address the potential coding

biases, they are asked to provide corrections to the recorded information. (It should be noted that the questionnaire was also designed to minimise the amount of coding required.)

4.5 Evaluation of Materials

One final step was taken to remove potential biases, such as biases due to the researchers' preconceptions, from the interview process. The first two interviews were used to pilot the questionnaire and the interview technique. The participants in these interviews were asked to evaluate the questionnaire and to suggest improvements to the interview process. Furthermore, two independent researchers studied the first interview and highlighted eighteen points that could be improved, or that required continued awareness from the researchers. In summary, these areas were:

1. minor changes to the interview pack;
2. clearer introduction and identification of the roles of the two researchers;
3. earlier identification of the participants role in the ICD process diagram;
4. the need to supplement the database entry with manual recording of a) initial information, b) changes to the ICD process model, and c) information about other contacts;
5. the need to be aware of the biases of the interviewee and the researchers, and the subsequent need to verify the information collected; and
6. the need to be aware of the difficulty of obtaining some of the requested information.

Changes to areas 1, 2, 3 and 4 were made before the remaining interviews in this study. Area 5 was addressed by asking the participants to focus on their area of expertise, through the early identification of the source of second-hand information, and through the requests for detailed information and examples requested for each problem area. Area 6 was addressed, as described in Section 4.3, by explicitly allowing the participants to provide examples as well as quantitative information about the detailed impact of problems.

5. Application of the Approach

Sixteen participants in the ICD process were interviewed. They included the C3I/IM Development Committee (the Gang of Seven, or the G7), three project managers, a C3I system user, and six other interviewees. One hundred and seven problems were recorded in the database, relating to thirteen main problem areas.

Four of these problem areas were highlighted as areas for further research, and examples of problems and potential solutions were identified for several of the thirteen problem areas (Henderson and Kingston 1999). One of the main benefits of the approach is that it enabled the identification of problem areas that are not specific to a particular project. Thus, it provides a more general overview of the ICD process than do "lessons learned" reports, which usually focus on a single project.

This is not intended to downplay the benefits of "lessons learned" reports. While they often contain subjective, sometimes biased, information, they also provide valuable, detailed, information about specific activities. With this in mind, the lessons learned while conducting the interviews are now discussed.

5.1 Guidelines

Sections 3 and 4 described an approach to investigating the problems in ICD. This section focuses on the experiences gained while conducting the interviews, both during the evaluation interviews, and the primary interviews.

During the interviews, the researchers had several objectives including eliciting information from the interviewees, recording the information, and developing a rapport with the interviewees. The researchers had to work together to accomplish these objectives. This was achieved by clearly identifying the roles of the researchers. Initial roles were identified before the first (evaluation) interview. However, teamwork is a complicated process, so the roles were refined based on an evaluation of the first interview. One researcher had prime responsibility for establishing a rapport with the interviewees and, for eliciting information on the ICD process model and associated problem domains. The other researcher had prime responsibility for recording the information and eliciting information during the evaluation of the problems. However, both researchers needed to share the responsibility for achieving all three objectives. It is recommended that researchers should share responsibilities in all interview-based studies. For example, while one researcher is engaged in conversation or recording information, the other researcher could try to identify potential threats to the validity of the information. A threat to the validity of the information arises when uncontrolled variables effect the information collected.

Three potential threats that are associated with the elicitation of information were identified in the ICD problem identification study.

First, the study participants tended to focus on problems that they had recently encountered or discussed. Refocussing the participants on other problems required considerable care. The preliminary discussions on the ICD process, combined with a general knowledge of the acquisition process, helped to identify problems associated with less recent ICD activities. However, in affecting the redirection, the researchers needed to be careful not to ask leading questions. This was particularly true with the quieter participants. (Note however, that most participants were forthcoming with information.) Consequently, a debriefing process after each interview that focuses on the actions of the researchers, and the interpretation of the results, is recommended.

Second, it was difficult to get additional information from the participants after the interviews. The researchers sent participants copies of the information recorded during the interview, and requests for additional information. However, in most instances, additional information was only obtained after several requests, and in a few cases, important, missing, information was not obtained even after several requests. Consequently, it is recommended that the researchers consider the priorities of the information of interest, and ensure that all the highest priority information is collected during the interview. Although the demands on the participants' time should be minimised, additional interviews should be scheduled if necessary.

Third, there is the potential for the information to be biased because of interpretation problems. This occurs when the researchers misinterpret information, and when participants identify problems about which they have only indirect knowledge. To avoid this problem, the researchers asked questions designed to clarify the nature of the problem. Some of the

questions, such as requests for examples and descriptions of the impact, were based on the questionnaire discussed in Section 4.2. However, the researchers also asked other questions on an *ad hoc* basis. For example, when one researcher was recording information, the other researcher was asking questions designed to ensure that the correct information was being recorded.

Information was recorded using a computer-based system, supplemented by a paper-based system. This process proved to have several benefits. First, it simplified the coding and analysis of the information as most of the information was coded as it was entered. Second, it provided an opportunity to verify the coding and the researchers' interpretations of the information. The study participants were given regular opportunities to comment on the coding of the information – particularly after lengthy periods of discussion. Third, it had an unanticipated benefit. In the first (evaluation) interviews, the computer was introduced at the start of the interview. Some of the participants stated that they found this daunting and/or distracting, so the introduction of the computer was delayed until the evaluation of the problem areas. This had an added benefit; the change seemed to stimulate some participants. Having previously stated that they could think of no more problem areas, several participants immediately identified other problem areas when the computer was introduced, usually about half-way through the interview. Participants also identified other areas as they discussed detailed information about a particular problem area.

However, the use of a computer can also have limitations. The researcher responsible for entering the information was able to touch-type with reasonable speed and accuracy. This enabled information to be entered with relatively few interruptions and delays to the discussions. (Note that the teaming arrangements already discussed were also necessary to ensure that the use of the computer did not silence the participants.) If researchers are unable to touch-type then, subject to security considerations, alternative arrangements – such as the use of tape-recorders – should be considered. However, researchers should be aware that additional effort might then be required to verify the information provided, and to ensure that the researchers and the study participants have a shared understanding of each problem area discussed.

6. Conclusions

The preceding sections of this report have presented and discussed the design and conduct of a study that has been used to investigate problems in the ICD process. Detailed results of the study are given in (Henderson and Kingston 1999). It is hoped that the results of this study will help to motivate process improvement activities in the ICD process. This section discusses how other researchers can benefit from the approach described in this report.

Repeated application of the approach can be used to monitor process improvement activities. The results of each study provide a record of the problems encountered in the ICD process at a particular point in time. As process changes are implemented, the problems encountered with the ICD process will change. Repetition of the approach could be used to identify areas where the process improvement activities have been successful, and areas where further changes are required. However, changes in strategic guidance and changes in technology will also affect the acquisition process. These changes should be considered by assessing the impact of process improvement activities. For example, traditional 'big bang' approaches were generally satisfactory, until the technological and strategic changes that lead to Defence's acquisition of

software-intensive C3I systems. Future changes could affect the suitability of ICD processes. Any assessment of process improvement activities needs to consider such changes.

In conducting these repetitions, or similar interview-based studies in other areas, the following points should be considered.

- **Evaluate the interview process**. While this report provides guidelines and suggested roles for participants, different research teams will have different dynamics that need to be explored and evaluated. Teams need to consider not only how they will work together when the process is implemented as planned, but also how to cope with deviations that arise when interviewing busy, sometimes distracted, people.
- **Be consistent in selecting interview participants**. It can be tempting to select interview participants in a manner that biases the results of the study. Potential participants should not selected (or ignored) just because of their familiarity with the research, their perceived contribution to the study, or their agreement (or otherwise) with the researchers pre-conceived ideas. While it might be easy to adhere to this principle at the start of the interviews, the temptation increases if selected participants are not available within the desired time period. For example, although it extended the duration of the study, the complete Gang of Seven was interviewed.
- **Identify the information to be collected.** Semi-structured interviews based around the information to be collected reduce the possibility of the researcher biasing the results of the study while still providing flexibility. A semi-structured interview process can help guide the interview and identify the roles of team members. It allows the information from the various participants to be collated and compared, and simplifies the analysis of the information.
- **Consider using tool support.** This reduces the amount of coding required after the interviews. Reiteration of the information as it is recorded provides a valuable opportunity for verification of the information – both for checking the participant's knowledge of the topic and for ensuring that the coding does not reflect the preconceptions or biases of the researchers.
- **Identify potential limitations early.** The time constraints of an interview, and the knowledge of the participants, mean that it is not always possible to collect all of the desired information during each interview. Researchers should consider alternative strategies that can be used if the participants are unable or unwilling to provide information, and how to ensure that the most important information is collected during the review.

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Appendix A

This appendix contains the flier used to inform the study participants about the purpose of the study. It was sent with a copy of the diagram in Figure 1, the questionnaire in Appendix B, and the sample problems in Appendix C.

Iterative Capability Development Preliminary Study – Information for Participants

Derek Henderson and Gina Kingston

Introduction

The aim of this study is to investigate the nature and severity of problems faced by Defence in the Iterative Capability Development (ICD) of Command and Control (C2) systems. Iterative capability development is a cyclic process where the capability evolves in an evolutionary way in response to changing operational requirements and new technology. It includes evolutionary acquisition but also focuses on other elements that need to be considered in the development of effective capability, such as high level planning, approval processes, research and development, and support.

Key stakeholders will be interviewed and their views sought on the major ICD issues. Interviews will be structured around a questionnaire developed by the researchers. Quantitative evidence relating to problems will be collected and stored for subsequent retrieval and analysis. This evidence will be used to develop empirical studies of specific problems in ICD that stakeholders agree are important. The output from the empirical studies will be a series of credible recommendations for improvements to ICD processes, which will ultimately result in the acquisition of more effective C2 systems.

Study Objectives	*Study Benefits (to participants and Defence)*
1. Identification of ICD problems. 2. Characterisation of the problems in terms of their nature, importance and impact. 3. Comparison of different stakeholder's perceptions of problems. 4. Development of a high level ICD process model. 5. Identification of a small number of critical problems, which can addressed in later, detailed empirical studies. The objective of these studies will be to uncover objective evidence to use as the basis of recommendations for process improvement.	Short term benefits 1. A better understanding of ICD processes for the development of C2 systems. 2. An understanding (and visibility) of the various problems in ICD processes. 3. Potential solutions to problems in ICD processes. Longer term benefits 1. Credible recommendations based on objective evidence, to critical problems in the ICD process.

The Researchers	*The Participants*
Derek Henderson and Gina Kingston work in the Software Systems Engineering (SSE) Group of Information Technology Division at DSTO. SSE group has provided advice on a consultancy basis to a number of projects including JCSE, AEW&C, Nulka, Starlight, and HFMOD. Derek has a wide experience in Defence and has recently conducted research into requirement specifications and Evolutionary Acquisition. Gina is currently studying Joint Reviews for her PhD and has a background in empirical methods.	Participants have been selected who have a key involvement in the ICD process. **Preparation. As a participant you should:** 1. Become familiar with the ICD model provided and understand how your role fits within the model. 2. Identify problems within the ICD process that you have encountered in your role. Completed sample problems are provided as examples.

Further reading

The following documents are provided in this information pack as background to the study:

1. Iterative Capability Development of Command and Control Systems – A Research Proposal – This paper provides an overview of ICD and briefly describes the proposed research program.
2. A questionnaire. Participants do not have to complete questionnaires; information will be entered directly into a database by a researcher during the interview.
3. A Model of the ICD process – This model represents our current understanding of the ICD processes and will be explained during the interview. We intend to evolve this model as we gain feedback from participants.

Contact details:

Derek Henderson Email: Derek.Henderson@dsto.defence.gov.au Tel: (08) 8259 7667 Address: ITD/DSTO, PO Box 1500, Salisbury, South Australia 5108	Gina Kingston Email: Gina.Kingston@dsto.defence.gov.au Tel: (08) 8259 6611 Address: ITD/DSTO, PO Box 1500, Salisbury, South Australia 5108

Appendix B: Questionnaire

This appendix contains the questionnaire used in the study. The questionnaire was used primarily as a guide to the information required. The participants were not required to complete the questionnaire. Instead, the information was entered directly into a database during the interviews. However, the study participants were left with a copy of the questionnaire in case they wished to provide information on additional problems not covered during the interview.

Interviewee:_____

Id:
Parent:

ICD Preliminary Study: Problem Elaboration Questionnaire

Part A: Descriptions

Problem Description: _____

Example: _____

Impact : _____

Potential Solutions : _____

Part B: Characteristics

How important is the problem?
Please answer according to your general impressions. Later questions will focus on specific criteria.

1 2 3 4 5 6 7 8 9 10
Low Importance High Importance

What is the time delay between the start of the activity involving the problem and its impact?

< 1 day < 1 week < 1 month
< 3 months < 1 year > 1 year

How frequently does the activity involving the problem occur?

Every week Every month Every year Every project
Other _____ (Please specify)

Who has authority to change the activity involving the problem?

_____

Consider the impact of the problem on the how C2 capability increments or (sub-) projects in the following areas. Give examples of the impact and then try to quantify the impact.

Area	*Example*	*Percentage Change*
Cost		
Schedule		
Quality		
Interoperability		
Client-Developer Relations		

Appendix C: Sample Problems

This appendix contains the worked examples distributed to the study participants before the interviews. It was sent with the flier in Appendix A, a copy of the diagram in Figure 1, and the questionnaire in Appendix B.

ICD Preliminary Study: Problem Elaboration Questionnaire

Part A: Descriptions

Problem Description: The incremental delivery schedule is so tight that we have difficulty providing full support in terms of documentation and training materials

Example: Increment 3.1 was delivered without any training manuals.

Impact: Users are becoming disenchanted with the project as they are disrupted by unsupported new increments.

Potential Solutions: Assign more staff to developing support documentation. Better project management.

Part B: Characteristics

How important is the problem?
Please answer according to your general impressions. Later questions will focus on specific criteria.

1 2 3 4 5 6 7 (8) 9 10

Low Importance — High Importance

What is the time delay between the start of the activity involving the problem and its impact?

< 1 day | < 1 week | < 1 month
< 3 months | < 1 year | > 1 year

How frequently does the activity involving the problem occur?

Every week | Every month | Every year | Every project
Other Every increment (Please specify)

Who has authority to change the activity involving the problem?
The Project Manager & the developer's Project Manager.

Consider the impact of the problem on the how C2 capability increments or (sub-) projects in the following areas. Give examples of the impact and then try to quantify the impact.

Area	*Example*	*Percentage Change*
Cost		
Schedule		
Quality	Lack of training materials effects the usability of the system	20%
Interoperability		
Client-Developer Relations	This problem has a detrimental effect on user/project relationship	20%

ICD Preliminary Study: Problem Elaboration Questionnaire

Part A: Descriptions

Problem Description: Difficulty obtaining access to appropriate users resulted in poor requirements, necessitating many costly changes to requirements.

Example: A user has recently realised that a collaborative tool would be a useful addition to his information system.

Impact: Redesign of architecture to accommodate new requirement.

Potential Solutions: Spend more time before design validating requirements. Take more time to find knowledgable users.

Part B: Characteristics

How important is the problem?
Please answer according to your general impressions. Later questions will focus on specific criteria.

1 2 3 4 5 6 7 (8) 9 10

Low Importance — High Importance

What is the time delay between the start of the activity involving the problem and its impact?

< 1 day | < 1 week | < 1 month
< 3 months | < 1 year | > 1 year

How frequently does the activity involving the problem occur?

Every week | Every month | Every year | Every project
Other _____ (Please specify)

Who has authority to change the activity involving the problem?
The Project Manager or the user representative.

Consider the impact of the problem on the how C2 capability increments or (sub-) projects in the following areas. Give examples of the impact and then try to quantify the impact.

Area	*Example*	*Percentage Change*
Cost	Architecture re-design added unplanned cost	10%
Schedule	Architecture re-design caused the schedule to blow out	10%
Quality		
Interoperability		
Client-Developer Relations		

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in the Iterative Development of C3I Capability

Gina Kingston, Derek Henderson and Rudi Vernik

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Gina Kingston, Derek Henderson and Rudi Vernik

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Electronics and Surveillance Research Laboratory
PO Box 1500
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19. ABSTRACT

This report presents a research approach that has been used to determine the key problems faced by the Australian Defence Organisation (ADO) in the iterative development of C3I capability. Repeated application of the approach, combined with knowledge of strategic and technological changes, could be used assess process improvement activities.

The approach uses interviews of the stakeholders in the Iterative Capability Development (ICD) process to gather information about the perceived problems. As well as documenting the approach used in a study of the key problems with the ICD process, this report illustrates the application of study design principals, such as methods for minimising potential biases in an interview-based study.